NASA Radiation Hardness Assurance (RHA) Standard: 2023-01 Status for JEDEC

Core Team: Razvan Gaza, Josh Pritts /JSC

Ray Ladbury, Michael Campola, Ted Wilcox, Jean-Marie Lauenstein /GSFC

Greg Allen, Leif Scheick /JPL

Acknowledgements: Pete Majewicz, Jonny Pellish /NEPP

Robert Hodson, John Holladay /NESC

Introduction

- Historically, NASA handled RHA at Center / Program / Project levels with radiation SME input
    - Center-specific standards, Program control plans / requirement documents
    - NASA-STD-8739.10 contains a radiation section but it is at high level
    - Some Program requirement documents rely on external RHA D&C Standards
        - SMC-S-010 “Air Force Space Command EEE Parts Standard” Appendix A covers RHA
- In 2019, NESC commissioned an RHA study under task TI-19-01489
    - Supported by NASA radiation/avionics SMEs from GSFC, LaRC, MSFC, JPL, and JSC
    - In 2021, the product was published “Avionics RHA Guidelines” https://ntrs.nasa.gov/citations/20210018053
    - Provides recommendation that an Agency-level RHA Standard be developed by OSMA
- The initial RHA Standard formulation effort was kicked off in 2022 and is funded by NEPP
    - This presentation shows the progress to date

RHA Standard Development Requirements & Challenges

- Need to envelop the entire NASA portfolio of programs and programs. These are very different in terms of:
  - Mission (class)
  - Environments
  - Application
  - Lifetime
- At the same time, there is a lot of commonality in the needs of the radiation engineering community
  - The RHA standard is intended to empower radiation engineers and inject RHA in the early project formulation and design
- Technology advancements challenge the traditional RHA paradigm
  - "Full characterization" of modern complex devices, part-level vs. system-level RHA
- The standard must not override existing Center, Program, or IP RHA Standards but rather augment them
  - Focus the "shall" statements on RHA process requirements: timeline, documentation, risk management
- Need to include technical rationale "the why"
  - Technology maturation leads to new threats
  - Not intended as a comprehensive RHA textbook
- Lack of a uniform RHA vernacular
  - "Radiation hard" "Radiation tolerant" "COTS" "EEE Part Grade"
  - The standard aims to establish an RHA taxonomy
- Must be consistent with existing NASA processes
  - Leverage the risk management system

There is no single "best RHA solution". MEAL tailoring is key to accomplishing mission objectives within the program constraints and risk tolerance posture

RHA Taxonomy

- No systematic method is currently defined to categorize EEE parts from the RHA perspective
- Initially, it was attempted the mirror the EEE Parts “grade” taxonomy
- Eventually, the Standard converged on instead categorizing RHA <u>approaches</u>
  - There is much more to RHA than selecting a part type
- Separate taxonomies are defined for SEE and TID/TNID
  - SEE shown as an example in the next slides
- There are currently five SEE RHA categories defined, and denoted S5-S1
  - S5 is “do nothing”, S1 is the equivalent of “old school rad-hard”
  - The description of each category includes several considerations
  - Details on next slides should be considered a draft… still in work
- Each mission class (SMD) & criticality (HEO) is associated with an RHA category
  - Implementing that category (or more stringent) provides confidence that objectives will be met consistent with the mission-acceptable risk tolerance posture
  - The association is not a “shall” statement… will circle back to this

SEE Taxonomy (1)

RHA Type	S5 (do nothing)	S4	S3	S2	S1
Human Space Flight Criticality Default	N/A	Crit 3		Crit 2R	Crit 1,2
Mission Class Default	N/A	D or 7120.x		C	A, B
Risk tolerance posture	Highest	High	Medium-High	Medium-Low	Low
Purpose of SEE RHA	N/A	Do no harm	Provide limited reliability assurance and/or quantification of DSEE risk	Provide assurance of reliability (DSEE) and availability (NDSEE) consistent with the Program risk tolerance posture	
RHA integral to the design process	No	No	Yes	Yes	Yes
Predominant EEE Parts Radiation Usage	Not driven by SEE	Non-RHA parts and CCAs	Non-RHA parts with pre-design screening or flight heritage[1].	RHA parts with risk avoidance or characterization data to medium LET (30-40 MeV-cm²/mg)	MILSPEC RHA parts with risk avoidance or characterization data to high LET (60-75 MeV-cm²/mg)[2]
Anticipated scope of systems engineering	None	Focused on do-no-harm to other system components	Is typical class D different from S5? Conversely, do statements for S1/S2 apply here too?	SEE threats to reliability and availability drive the system architecture. Use of rad-tolerant parts vs. rad-hard may have significant implications to system availability in the radiation environment and can lead to dramatic increase in the radiation systems engineering effort.	
Anticipated scope of SEE design	None	None to interface-limited[3]	Current monitoring, current limiting, watch-dog timers, autonomous power cycling, etc.	SEE threats to reliability and availability drive the circuit & SW/VHDL design. Part selection for risk avoidance (i.e., SEE rad-hard vs. rad-tolerant) lowers SEE design scope vs. analysis-driven design mitigation implementation	
Anticipated scope of SEE testing	None	CCA-level high energy proton testing	Combination of CCA- and part-level, high-energy proton and heavy ion testing[4]	Piece-part heavy ion characterization test data should be available. Additional testing as needed for NDSEE characterization, low-LET-threshold parts proton susceptibility, and CCA-level for complex system interactions (e.g., SW and HW) validation.	

[1]Relevant and statistically significant
[2]60-75 MeV-cm2/mg may be tailored for benign environments
[3]E.g., implementation of current monitoring and power cycling capability external to the CCA
[4]High energy protons (~200 MeV) often used as the main test solution. Heavy ion testing performed for specific part types e.g., with thick sensitive regions [RHA guidelines]

SEE Taxonomy (2)

RHA Type	S5 (do nothing)	S4	S3	S2	S1
Human Space Flight Criticality Default	N/A	Crit 3		Crit 2R	Crit 1,2
Mission Class Default	N/A	D or 7120.x		C	A, B
DSEE part selection (survivability) criteria	**Not enforced**	**Enforced**			
SEGR/SEB/SEDR acceptance criteria	None	High energy protons for DSEE[5]	Test-constrained (e.g., 20 MeV-cm²/mg)	Risk avoidance (37 MeV-cm²/mg)	
SEL acceptance criteria	None			Risk avoidance (37-75[6] MeV-cm²/mg) or quantification	
DSEE data source	None	CCA-level test	CCA- and/or piece-part	Piece-part characterization	
Risk assurance result	None	Limited risk analysis[7]	Limited risk analysis	Verified risk avoidance or quantification	
A priori confidence reliability will be met	None		Limited	Risk quantification: Up to high[8] Risk avoidance: Superior	
NDSEE part selection (availability) criteria	**Not enforced**			**Enforced**	
NDSEE acceptance criteria	None			Risk avoidance: threshold or max piece-part rate requirement Risk quantification: full characterization requirement	
Typical NDSEE data source	None	CCA-level test	CCA- or piece-part test	Piece-part characterization	
Risk assurance product	None	Limited risk analysis[9]		Full analysis characterizes and quantifies probability of all unmitigated SEE at the interface	
A priori confidence availability will be met	None			Risk avoidance: Superior[10] Risk quantification: Up to high[8]	

[5]DSEE risk remaining for specific part types e.g., with thick sensitive regions [RHA guidelines]
[6]60-75 MeV-cm2/mg may be tailored for benign environments
[7]Proton-data-derived heavy ion DSEE susceptibility quantification is unreliable
[8]With successful implementation of SEECA-, and Systems Engineering tasks
[9]See RHA Guidelines Document for CCA-level test limitations
[10]Does not eliminate the need for SEE analysis (need to clarify this statement)

SEE Taxonomy (3)

RHA Type	S5 (do nothing)	S4	S3	S2	S1
Human Space Flight Criticality Default	N/A	Crit 3		Crit 2R	Crit 1,2
Mission Class Default	N/A	D or 7120.x		C	A, B
SEE RHA activities					
SEE circuit and criticality analysis (SEECA)	N/A	Component SEE analyses limited by design insight and statistics. CCA-level test observables must enable do-no-harm validation at system level as applicable.	Design and test strategy informed by SEECA. SEE mitigation analysis may be limited by test observables and statistics. Test observables must enable do-no-harm validation at system level as applicable.	SEECA informs part selection, design and test strategy. High resolution SEE circuit analysis is enabled by detailed part-level characterization data, including downstream non-recoverable effects of SET[11]. Full tracing of SEE impacts at circuit, assembly, and system level informs threat mitigation and risk acceptance.	
Complex parts test and analysis		Characterization of high level observables (e.g., SEFI) in the flight application	Use SEECA to determine if characterization at element & function level is needed to meet objectives	Characterization at element & function level by default. Complexity of modern electronics (and proprietary design) may limit the ability to obtain full characterization; holistic approaches to SEECA and testing may be required to inform risk quantification.	
High-current SEE		Confirmation of mitigation/recovery by radiation test[14]		Confirmation of mitigation/recovery by radiation test[14] and confirmation of no latent damage[12]	
Other non-recoverable SEE		Risk assessment for less-common non-recoverable SEE[13] recommended as feasible		Systematic risk assessment for less-common non-recoverable SEE[13]	
Similarity[15]		Recommended as feasible		Required. Specific situations including new technologies require SEE LAT.	

[11]Generic SET waveform use requires holistic assessment of margin in the context of application criticality. Application-specific SET tests required for insufficient margin and/or critical applications

[12]Reference GSFC note, summarize Ray's input of what is acceptable

[13]Including but not limited to I_{GS} degradation (micro-SEGR), NVROM bit flips, stuck bits, etc.

[14]With sufficient statistical significance

[15]Analysis required to validate applicability of previous test data to the flight design

RHA Process Requirements

	Project Formulation				Project Implementation						Program
	Pre- Phase A	Phase A		Phase B	Phase C		Phase D		Phase E	Phase F	
	KDP A	KDP B		KDP C	KDP D		KDP E		KDP F		
	MCR	SRR[1]	SDR	PDR	CDR	SIR	ORR	FRR	DR	DRR	FRR
Assign RHA Lead	RAD3										
RHA Feasibility	RAD4	Update as necessary									
Taxonomy		RAD5, RAD6									
IRCP		Initial (RAD8)		Update	Final						
ERD/EDD	Preliminary estimates	Initial (RAD7)		Update	Final						
Rad Analysis Reports				Initial (RAD9)	Mature (RAD10)	Update as necessary					Final (RAD11)
Parts List Rad Review				Initial	Update	Update as necessary					
Test Schedule Plan incl RLAT[2]				Initial	Update	Update as necessary					
Subsystem Rad Req Allocations[3]		Initial		Update	Final						
Radiation Risk		If required per RAD6, then track to closure									
	equired per RAD2, then track to closure										
System-level Rad Analysis & Report[4]					Inputs (RAD10)	Update as necessary					Final (RAD11)

[1]SRR or Standards Adjudication or equivalent, whichever occurs earlier

[2]Different types of tests are subject to different schedule drivers, some beyond the project control. For example, SEE test schedule is constrained by access to beam time. RLAT is constrained by sample procurements and irradiation time for ELDRS testing.

[3]Strongly recommended as an enabler of radiation verification activities. Ideally, quantitative reliability and availability allocations should be imposed on subsystems / devices. If this approach is unfeasible, high level requirements usually need to be interpreted in terms of measurable parameters in consultation with design and project engineers.

[4]As required for system integration. Depth may be tailored depending on Program or project or may not be applicable.

RAD 1 The schedule of RHA Activities shall comply with Table 1.

RAD2 If at any time during the program or project life cycle the schedule of RHA activities deviates from Table 1 or the deliverables are insufficient, programs and projects shall accept a radiation risk and formulate a mitigation plan.

RAD6 If at any time the RHA approach does not meet or exceed the default for mission class/criticality, programs and projects shall accept a radiation risk and formulate a mitigation plan

The program and project life cycles are consistent with the NASA Project Life Cycle described in NPR 7120.5F

NASA Agency RHA Standard 2023-01 JEDEC JC-13.4

Table of Contents

Contents

Summary and Conclusions

- Development of a NASA Agency level RHA Standard is underway and funded by NEPP
- The development strategy recognizes and addresses specific requirements and challenges
- Targeting a mature draft by the end of the current FY
- Critique, thoughts, suggestions, expressions of interest to act as a potential external reviewer (TBD) welcome
- razvan.gaza@nasa.gov

Thank you for your attention!

List of Acronyms

BLUF: Bottom Line Up Front

CCA: Circuit-Card Assembly

COTS: Commercial-off-the-Shelf

D&C: Design and Construction (Standards)

DDD: Displacement Damage Dose

DSEE: Destructive SEE

EDD: Environments Definition Document

HEO: Human Exploration and Operations Mission Directorate

HW: Hardware

IRCP: Ionizing Radiation Control Plan

LET: Linear Energy Transfer

MEAL: Mission, Environment, Application, and Lifetime

MIL-SPEC: Military Specification

NDSEE: Non-destructive SEE

NEPP: NASA Electronic Parts and Packaging Program

NESC: NASA Engineering & Safety Center

NSPAR: Non-Standard Part Approval Request

NVROM: Non-Volatile Read-Only Memory

OSMA: (NASA) Office of Safety and Mission Assurance

RHA: Radiation Hardness Assurance

RHA Part: Radiation Hardness Assured Part

SEB: Single-Event Burnout

SEGR/SEDR: Single-Event Gate/Dielectric Rupture

SEE: Single-Event Effect(s)

SEECA: SEE Criticality Analysis

SEFI: Single-Event Functional Interrupt

SEL: Single-Event Latchup

SET: Single-Event Transient

SEU: Single-Event Upset

SME: Subject Matter Experts

SMD: Science Mission Directorate

SRR: System Requirements Review

SW: Software

TID: Total Ionizing Dose

TNID: Total Non-Ionizing Dose

VHDL: VHSIC (Very High Speed Integrated Circuits) Hardware Description Language